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Track-Based Vehicle Dynamics Analysis and Performance Evaluation of the Aprilia RS660

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Abstract

Throughout motorcycle engineering understanding and interpreting data can give greater insight to bike and rider behaviour. In this paper fundamentals of motorbike and rider dynamics were explored and a two of studies completed to assess rider dynamics, bike engine and torque mapping, suspension characteristics and handling. The Aprilia RS660 was subject to a dynamometer test, this was completed to analyse the torque map of the engine. Additionally, the Aprilia RS660 was taken to Pembrey circuit to gather data on rider inputs and bike dynamics. A descriptive methodology of these studies was written and compared with other current studies. Additionally, suggested alterations that could improve the validity of the studies conducted was discussed.

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1.0 Introduction

A study was conducted to assess the effects of set up alterations on the Aprilia RS660 and its rider. The aim of this report is to interpret various data sets and propose intellectual ideas as to what they indicate in terms of motorcycle characteristics. Data from the bikes and the rider's suit were collected and analysed to characterise the handling behaviours. The Aprilia RS660 underwent a session on the dyno which allowed for torque mapping of the engine. Furthermore, the Aprilia RS660 completed laps at Pembrey circuit to collect rider data and assess rider input's effect on the vehicle. The overall objective of these studies was to develop an understanding of different bike and rider characteristics while proposing solutions and improvements to undesirable features.

2.0 Literature Review

2.1 Motorcycle Dynamics

Fundamentals of motorcycle handling are rake, trail, wheelbase, suspension, damping as well as tyre behaviour. Many of these elements have adjustability while others are largely dictated by the manufacturing and design decisions. However, altering the factors that can be controlled can significantly change the bike's handling and the way the rider handles the bike. If altered correctly they can offer a significant on-track advantage.

Cossalter, Lot and Massaro, (2014) characterise the bike as six main bodies: the rear wheel, swing arm, chassis, handlebar, front unsprung mass and front wheel. Furthermore, they highlight key geometry to a motorcycle's stability as 'wheelbase p , normal trail a_n and caster angle ϵ '. Cossalter, Lot and Massaro, (2014) and Motorcycle Handling and Chassis Design the art and science Foale, (2002) cover the importance of geometry's influence on handling characteristics; wheelbase, trail, fork angle and triple clamp offset as key features; these are summarised in Table 1.

Table 1: Motorcycle Geometry Overview

Geometry	Definition	Effects on Behaviour
Wheelbase	The distance between the centre point of the wheels	The shorter the wheelbase the more responsive and agile the bike. However, it decreases stability at high speeds
Trail	The horizontal distance from where the steering axis meets the ground and the tyres contact patch on the ground	The greater the trail the more stable the bike. However, the steering can feel heavier to the rider and less responsive
Fork Angle	The angle of the forks relative to the ground (value should be between 0 and 90)	The steeper the fork angle the more agile the bike. However, this sacrifices high speed stability

Triple Clamp Offset	The distance between steering axis stem and front forks in the y-axis. See Figure1	The greater the offset the bike will be more agile and responsive to steering inputs
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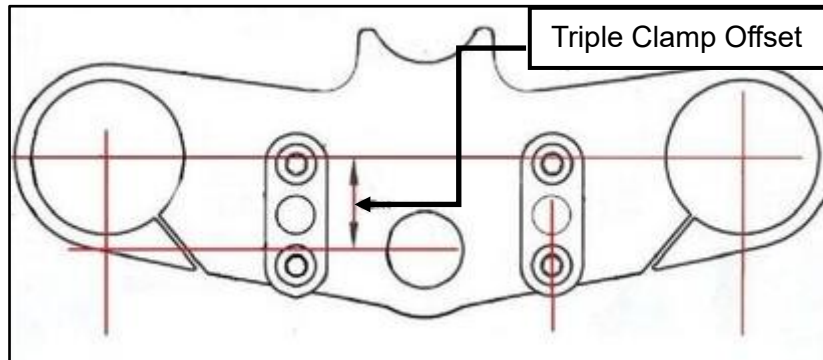


Figure 1: Triple Clamp Offset Measurement Diagram

2.2 Rider Dynamics

Motorcycles rely heavily on rider inputs such as steering torque, body position and throttle position to maintain balance. Cossalter, (2006) highlights that rider load distribution and motion significantly affects roll dynamics, steering response, and load transfer, particularly during cornering. Many papers are being published pertaining to this topic as it is a subject of much discussion within this motorbike analysis.

Several studies have modelled the rider as a dynamic subsystem connected to the motorcycle not as an independent entity. Zhu, Murakami and Nishimura, (2012) demonstrated that rider posture and arm stiffness directly affect the handling stability. Therefore, rider behaviour must be considered to generate an accurate dynamic model. Similarly, Kuroiwa, Baba and Nakata, (1995) showed that rider input and perceived handling are closely linked to torque delivery and steering response during manoeuvres such as lane changes. This also links with handling predictability and rider confidence.

Recent research has heavily emphasised the influence of rider corrections on motorcycle stability and performance; Kooijman and Schwab, (2013) reported that at low velocity corrective actions have a significant effect on motorcycle behaviour, while vehicle dynamics

become more influential at higher speeds. This underlines the importance of the interactions between the rider and motorbike.

2.3 Comparative studies

2.3.1 Evaluation of Motorcycles' Handling and Stability Under Slalom Conditions

A comprehensive stability and handling study was conducted by Tianjin Internal Combustion Engine Research Institute (Sun *et al.*, 2025). Sun *et al.* analysed the stability and handling of multiple motorbikes with numerous riders on a slalom course. It is key to note that in their analysis they considered stability and handling to be two independent factors. To objectively evaluate the indicators of these two features, only roll angle and steering torque were used as input variables. This limited the scope of the study and was not a true representation of the motorbike's behaviour as a whole as these are not truly independent factors.

Furthermore, by only considering the vehicles' behaviour while completing a slalom course it further narrows the possible analysis of the motorbike. This study was able to make some statements and draw some 'correlations between the index and the rider's subjective evaluations' this was not an overall assessment of the motorbikes' stability or handling or the relationship between them (Sun *et al.*, 2025).

2.3.2 A Motorcycle Riding Simulator for Assessing the Riding Ability and for Testing Rider Assistance Systems

This study focuses on the interaction between the rider and the motorbike and how the rider affects the bikes' dynamics. Page 8 'Measurement of Rider's Action' Cossalter *et al.*, (2006) discusses the methods used to interpret the rider's input. The page outlines common inputs that have sensors on motorbikes: 'handle-bars, accelerator, front and rear brake and gear'. This study then discusses details pertaining to the use of strain gauges on the handlebars; this data can then be interpreted to know the torque placed through the handlebars by the rider. The same method was used on the handlebars and foot pegs on the Aprilia RS660.

While this report contains no data collection it does support the data collection methods used in this study, particularly with respect to the Aprilia RS660.

3.0 Background Information on the Aprilia RS660

3.1 Aprilia RS660



Figure 2: Photograph of the Aprilia RS660 used for Studies

The Aprilia RS660 is a sport bike with a ‘front-facing 660cc Euro 5+ twin cylinder engine’ which is capable of outputting 105hp (Aprilia, 2026). Geometry measurements (Table 2) of the Aprilia RS660 were taken; this helped generalise the expected characteristics of the bike. The wheelbase aligns with the expected values for sports bikes oft used in racing. The Aprilia RS660 used was fitted with a OxTS AV200 logger as well as the sensors seen in table 3 (chapter 3.2).

Table 2: Aprilia RS660 Geometry Measurements and Calculations

Measurement	Value Measured	Units
Wheelbase	1390	mm
Front Wheel Radius	300	mm

Rear Wheel Radius	314	mm
Fork Angle	66.45	degrees
Triple Clamp Offset	30.0	mm
Trail	87.14	mm
Swingarm Length	540	mm

$$Trail = Front\ Wheel\ Radius * \sin(90 - Fork\ Angle) - \frac{Triple\ Clamp\ Offset}{\cos(90 - Fork\ Angle)}$$

Front Wheel Radius=300mm

Fork Angle=66.45°

Triple Clamp Offset=30mm

$$Trail = 300 * \sin(90 - 66.45) - \frac{30}{\cos(90 - 66.45)} = 87.14$$

*Equation 1:
Trail
Calculation
for Front
Wheel for
the Aprilia
RS660*

3.2 Aprilia RS660 Sensors

Table 3: Aprilia RS660 Sensor Information

Sensors	Measures	Reason for Sensor
OxTS AV200 (logger)	Measures motion using Inertial Measurement Unit (IMUs) and Global Navigation Satellite System (GNSS)	From the measurements many factors can be known such as: Positioning, velocity, acceleration, roll angle, yaw rate. (Oxford Technical Solutions Ltd., 2021)
Fork travel sensor	Change in voltage caused by the change on sensor length	Knowing the distance and rate that the forks compress at gives rise to the suspension behaviours.
Brake pressure sensor	Change in voltage caused by the change on sensor length	Can be used in support finding of load transfer and deceleration. In addition to rider behaviour analysis

Throttle position sensor	Change in voltage caused by the change on sensor length	Knowing the timing and throttle percentage can inform to the rider confidence in the vehicle as well as the stability and responsiveness of the bike.
Handlebar strain gauges	Change in voltage from the change in resistance caused by the extension/compression of the gauges	Knowing the force the rider is exerting on the handlebars can highlight the steering effort and indicate the level of counter steer being applied
Footpeg strain gauges	Change in voltage from the change in resistance caused by the extension/compression of the gauges	Knowing the force the rider is exerting on the footpegs can highlight the lean effort
Steering Angle	Analog measurement	Knowing the steering angle can highlight handling issues and inform to rider confidence and handling mechanics

3.2 Riders' Suit

The riders suit used for both track studies contained a 2D logger. The logger collects data of GPS speed, GPS yaw, acceleration and gyros in x, y and z.

4.0 Methodology

4.1 Aprilia RS660 Dynamometer

Dynamometer testing was conducted to characterise the steady-state torque output of the Aprilia RS660 across a range of engine speeds and throttle positions, where throttle position and gas delivery were 1:1. The motorcycle was securely mounted to minimise external disturbances to the MAHA MSR 400 motorcycle chassis dynamometer. Prior to data collection, the motorbike underwent one run to warm the engine and ensure the dyno was operating correctly. Engine speed and torque output were recorded digitally through the dynamometer control system, while throttle position was held constant by the rider. At each operating point, sufficient time was allowed for torque output to stabilise, ensuring that the results reflected steady-state engine behaviour rather than transient effects.

4.2 Aprilia RS660 Pembrey

The Aprilia RS660 completed laps of Pembrey circuit with no changes to the vehicle's set-up. The bike and suit data were downloaded from the loggers and stored for analysis. Pembrey circuit is 2.4km circuit with predominantly right-handed corners and flat-out sections (Figure 3). On the day of testing, weather conditions were poor. The track surface was damp due to the rain. This was important to consider when assessing the data from Pembrey.

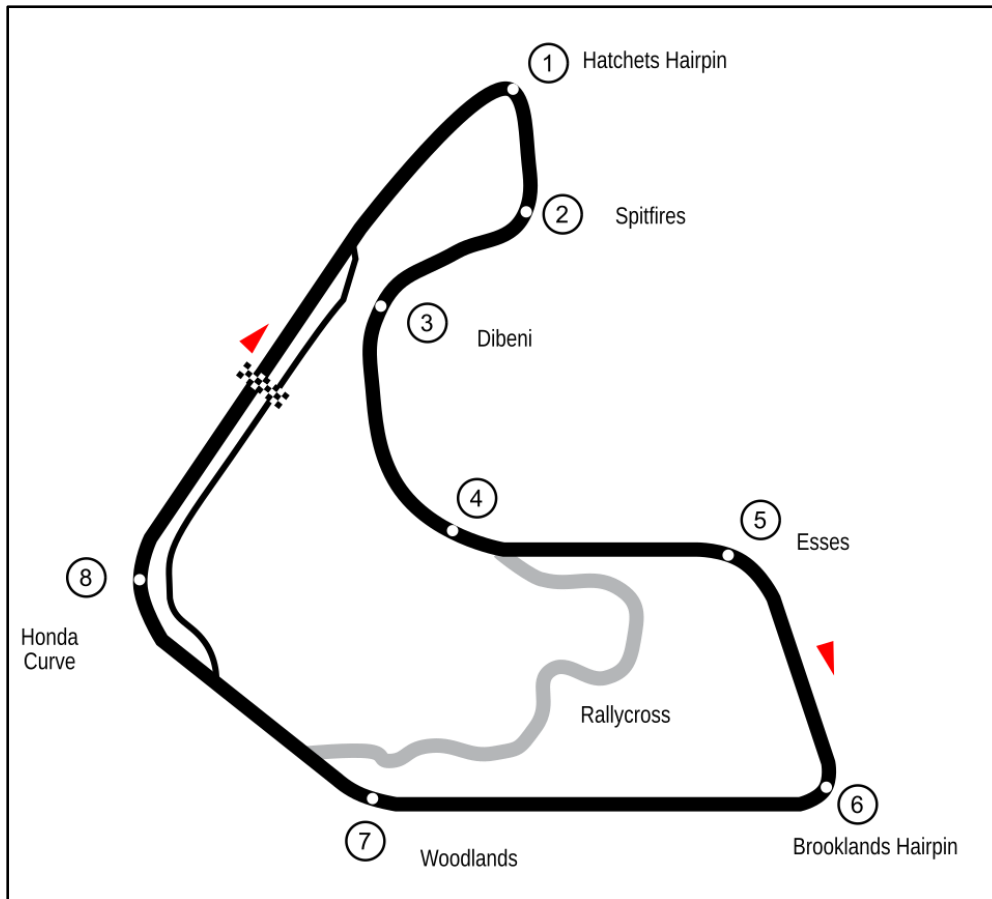


Figure 3: Track Map of Pembrey Circuit

4.2.1 Data Channel Selection Justification

Data channel selection seen in chapter 5.2 were based on established motorcycle dynamics principles. Throttle, wheel speed, acceleration, lean angle, suspension travel and brake pressure allowed for identification of traction limits, handling and stability as widely adopted in motorcycle handling analysis (Cossalter, 2006; Sharp, Robin S. and Limebeer, 2001; Pacejka, 2012).

5.0 Results

5.1 Aprilia RS660 Dynamometer

Table 4: Data from the Aprilia RS660 Dynamometer

Throttle Position (%)											Revolutions per minute (RPM)														
50	40	35	30	25	20	15	10	8	6	4	4175	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10,000	10,500	11,000
Torque at the Rear Wheel (Nm)																									
53.648	54.023	53.86	48.614	44.988	39.723	36.046	25.971	21.265	18.147	7.212															
59.411	59.29	58.376	54.355	48.945	43.123	38.54	27.367	23.659	18.239	3.26															
62.431	61.803	59.92	55.554	49.802	43.959	38.329	28.747	24.62	16.868	3.226															
63.341	62.046	59.533	54.833	48.817	43.208	36.674	28.55	23.112	13.905																
63.533	61.241	58.203	53.054	47.187	41.179	34.613	27.271	20.506	9.452																
62.58	59.346	56.393	51.324	45.393	38.882	32.709	25.235	16.904																	
62.386	58.147	54.825	49.94	43.955	37.192	31.347	22.711	13.136																	
61.841	56.835	53.274	48.574	41.851	35.606	30.173	20.56	10.357																	
60.477	55.251	51.628	46.862	39.497	33.676	28.733	17.882																		
59.527	54.001	50.558	44.779	37.534	31.704	27.284																			
58.686	53.35	50.056	44.108	36.489	31.376	25.893																			
57.923	52.532	49.269	43.19	35.322	29.81	23.771																			
56.529	50.984	47.305	40.893	33.547	27.534	20.751																			
55.135	48.949	44.308	37.887	30.67	25.235	17.795																			
53.147	48.046	41.046	35.573	27.904	23.211	14.509																			

100	90	80	70	60	
52.238	49.076	47.899	53.46	50.964	
57.93	56.583	56.87	58.347	57.38	
60.613	59.765	60.356	61.013	61.146	
62.586	61.808	62.23	63.074	62.91	
63.365	62.553	63.158	64.198	63.924	
64.369	63.566	63.909	64.694	64.003	
65.389	64.616	64.689	65.246	64.521	
66.436	65.633	66.069	66.848	65.141	
69.151	68.584	68.704	68.384	65.266	
71.788	70.854	69.977	68.703	64.909	
72.052	71.431	70.29	69.011	64.712	
72.452	71.951	70.589	68.863	64.351	
72.51	72.108	70.447	67.854	63.318	
71.774	71.389	69.609	66.457	62.14	
71.016	69.709	67.741	64.923	60.952	

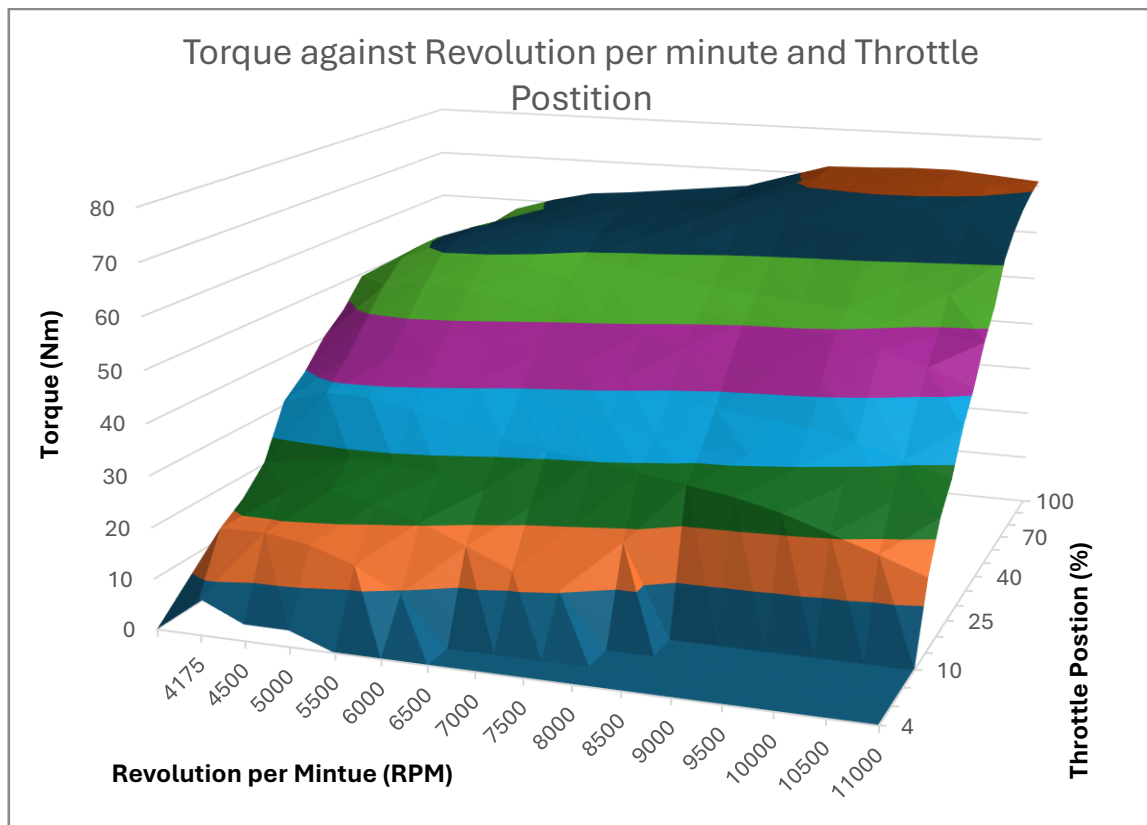


Figure 4: Graph of Torque against Throttle Position and RPM

5.2 Aprilia RS660 Pembrey

5.2.1 Throttle Position and Rear Wheel Speed

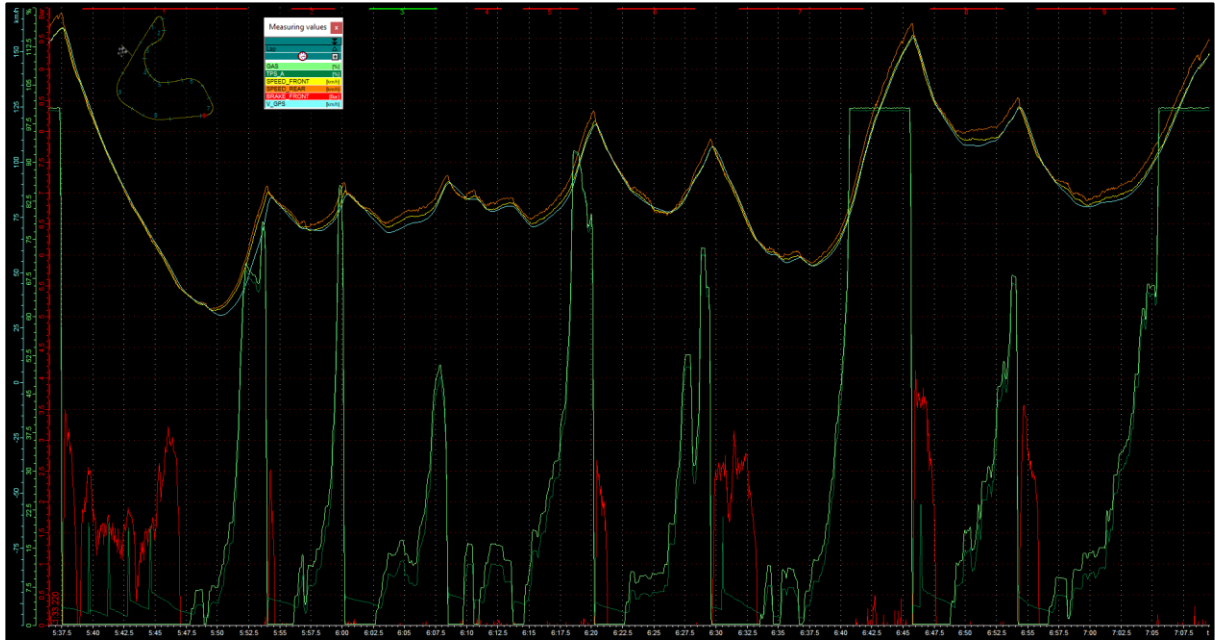


Figure 5: Graph of Brake Pressure, Throttle and Speed of Fastest Lap Session 2

5.2.2 Throttle Position and Longitudinal Acceleration

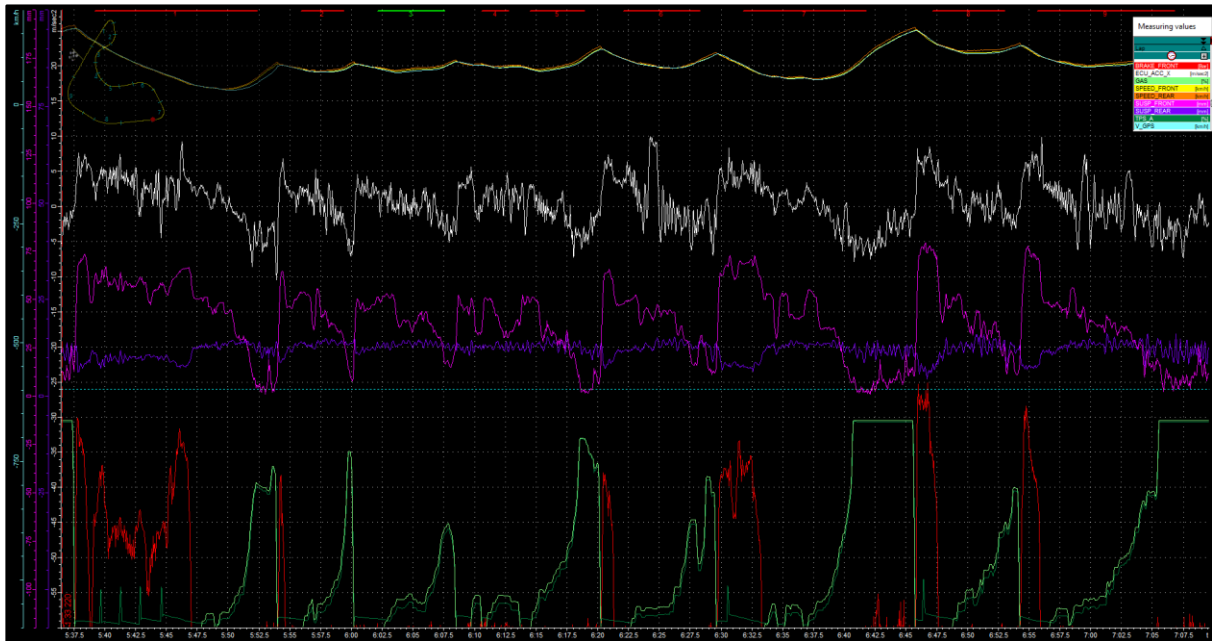


Figure 6: Graph of Brake Pressure, Suspension Travel, Acceleration in x Throttle, Front Brake and Speed of Fastest Lap Session 2

5.2.3 Suspension Travel and Brake Pressure

See Figure 6.

5.2.4 Lean Angle and Throttle Position

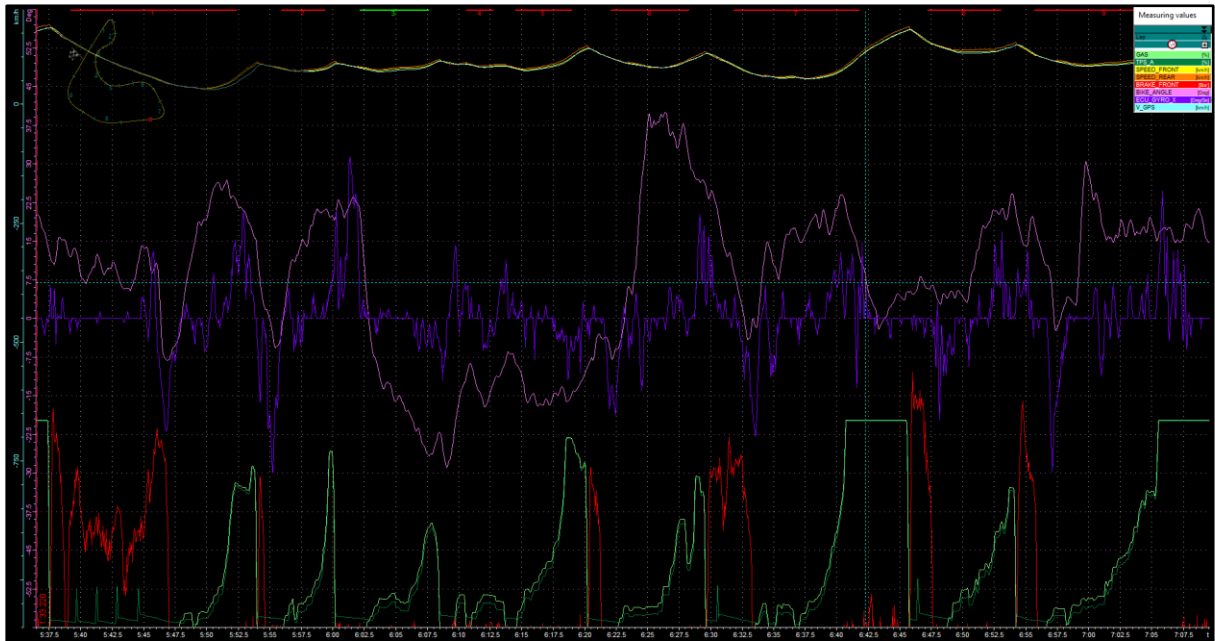


Figure 7: Graph of Bike Lean Angle, and Gyro about the x-axis, Throttle, Front Brake and Speed of Fastest Lap Session 2

5.2.5 Bike Lean and Rider Lean

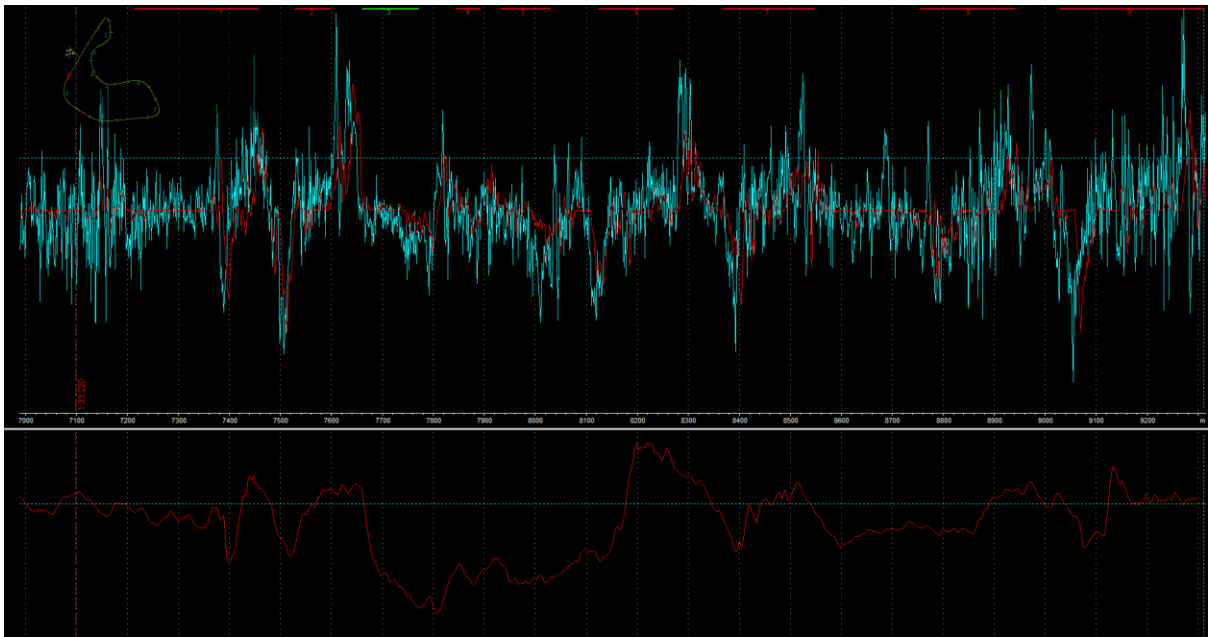


Figure 8: Upper Graph- Bike and rider Gyro about the x-axis and Speed of Fastest Lap Session 2 Lower Graph- Bike Lean Angle

5.2.5 Strain Gauge Data

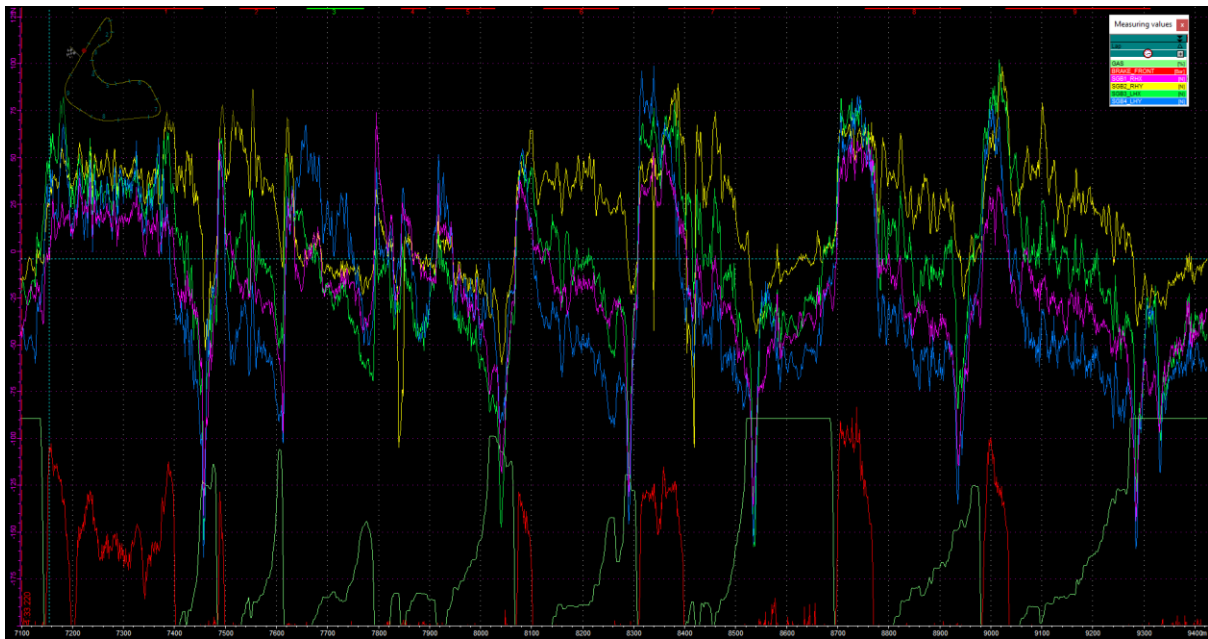


Figure 9: Graph of Strain in Handlebars, Throttle and Front Brake of Fastest Lap Session 2

6.0 Analysis

6.1 Aprilia RS660 Dynamometer

The dynamometer results demonstrate that the Aprilia RS660 has broad and progressive torque delivery across most of its operating range. Maximum torque output was 72.51Nm observed at 10,000 rpm with 100% throttle. The bike has a wide operating range from its RPM as noted by Cossalter, (2006), engines with wide usable torque bands reduce the need for frequent gear changes and enable smoother rider control, particularly during corner exit where stability and predictability are critical. Furthermore, the torque does not suddenly increase or decrease with changes in RPM or throttle position. This further supports the idea that this bike is stable and has predictable handling. This broad torque plateau is characteristic of modern parallel-twin sport motorcycles designed to prioritise rideability and controllability rather than narrow peak of performance.

At low throttle openings there is reduced sensitivity, with torque output remaining relatively minimal and heavily dependent on engine speed. This can be beneficial for maintaining control in mid-corner or low-grip conditions where low-throttle openings are used. As throttle opening increases beyond 50%, torque rises smoothly and approximately linearly with engine speed, with no abrupt transitions observed. Figure 10 and Figure 11 show the trend lines for torque output at different throttle positions. This behaviour suggests deliberate torque shaping via the electronic throttle control system. Guzzella and Onder, (2010) report that modern ride-by-wire strategies are designed to reduce nonlinearity between rider input and engine torque in order to improve drivability and rider confidence.

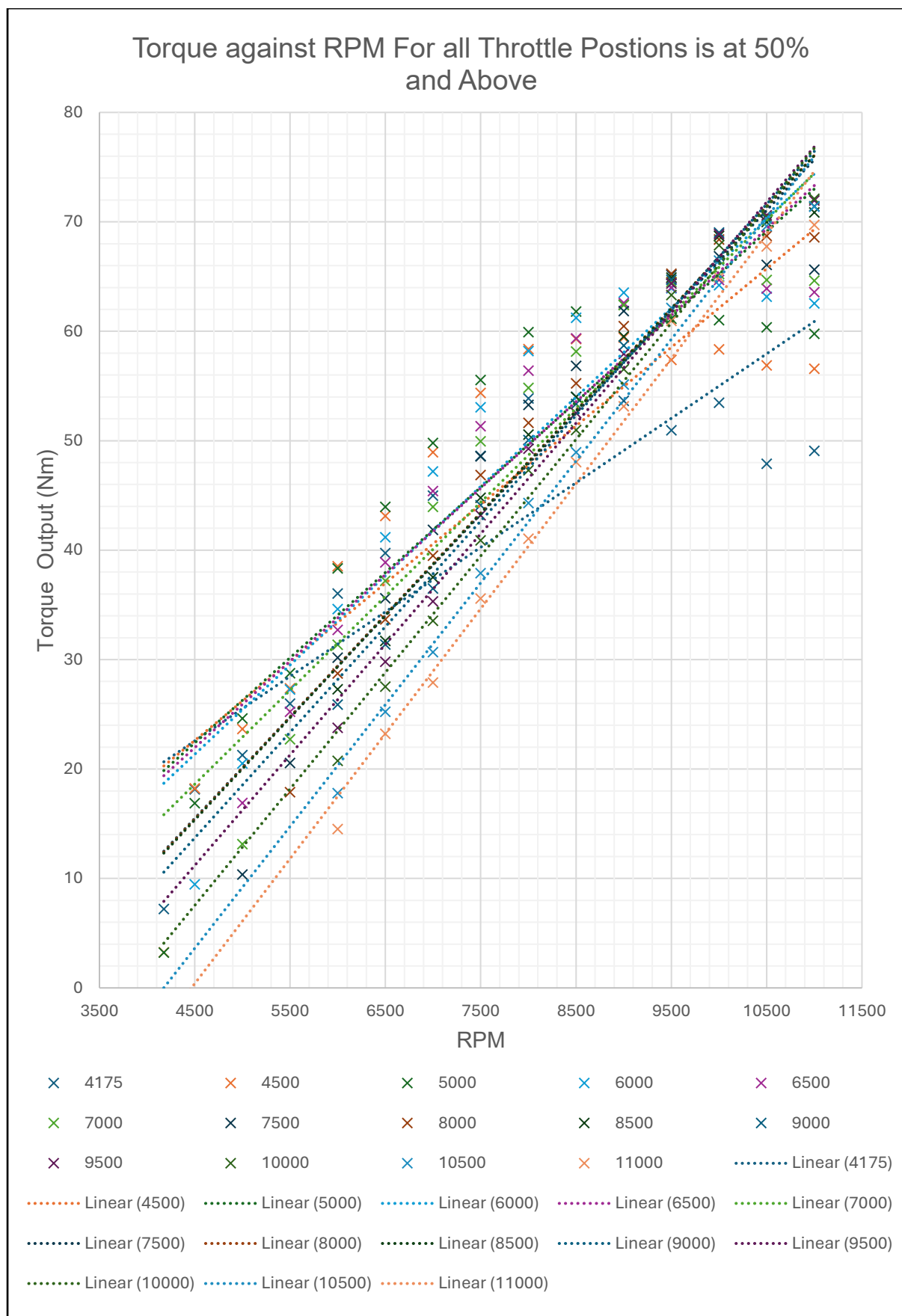


Figure 10: Torque against RPM For all Throttle Positions is at 50% and Above

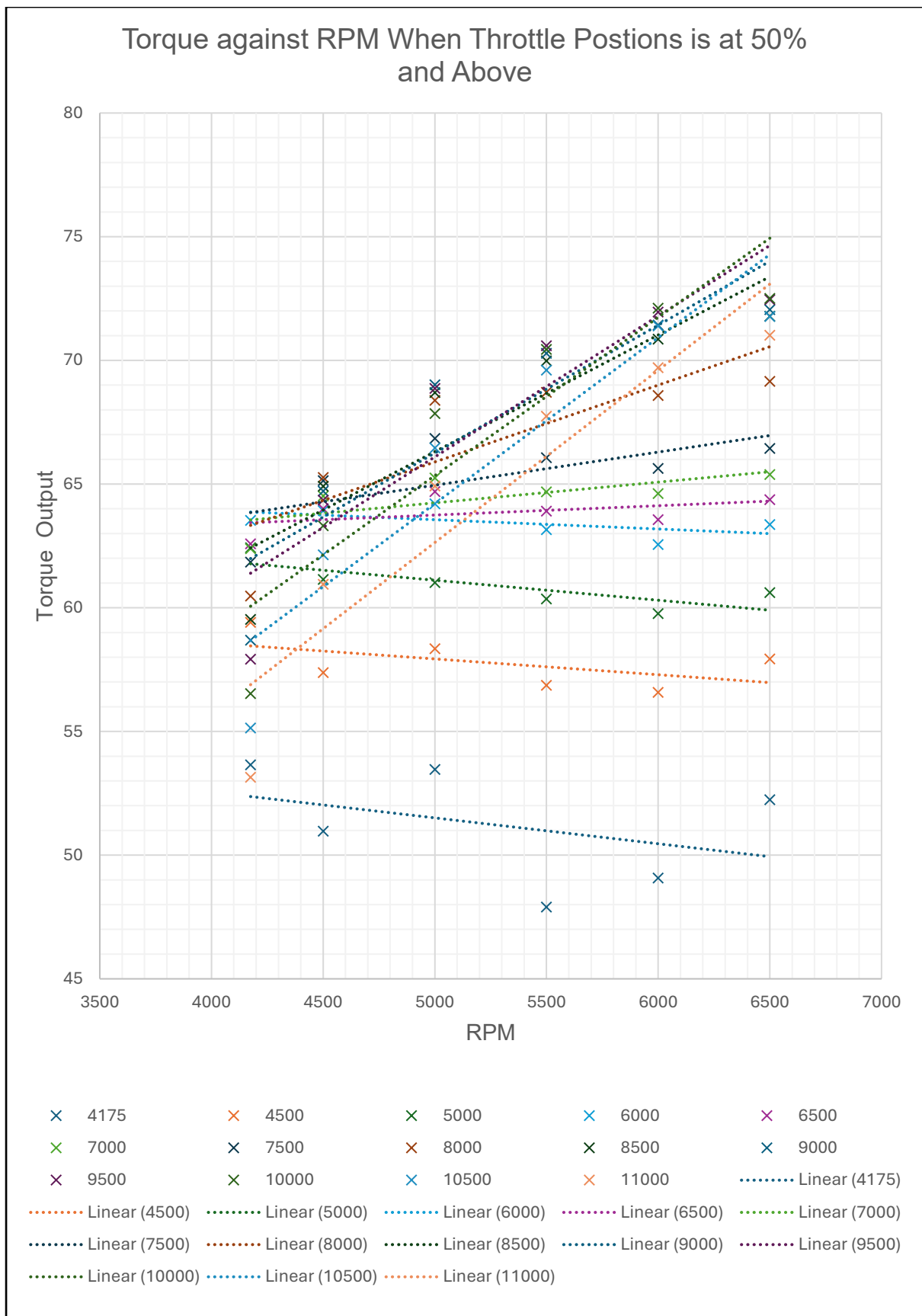


Figure 11: Torque against RPM When Throttle Position is at 50% and Above

At high throttle percentages and engine speeds the torque reduces gradually. This reduces the likelihood of aggressive acceleration and contributes to stable motorcycle dynamics. Studies by Kuroiwa, Baba and Nakata, (1995) and Zhu, Murakami and Nishimura, (2012) show that smoother torque delivery reduces the magnitude of corrective inputs such as steering, thereby improving handling. While this study does not capture transient throttle behaviour or tyre traction effects, the results give a valuable insight into how engine torque characteristics influence rider control and handling performance.

6.2 Aprilia RS660 Pembrey

6.2.1 Throttle Position and Rear Wheel Speed

Figure 12 showed throttle position percentage (TPS_A, dark green) and gas percentage (GAS, light green) showed a delay in response from the rider input to the delivery of fuel. Particularly when at lower TPS_A values. This may have influenced the rider's confidence in the bike and could be altered with electronic manage if desired.

TPS_A increases generally aligned with responses in rear wheel speed, indicating effective torque transmission. However, several regions exhibit a rapid increase in rear wheel speed (orange) which significantly exceeded front wheel speed (yellow) immediately after throttle application, suggesting that the rear tyre may be slipping. This can be managed by the rider or a traction control system. This aligns with established methods for identifying traction-limited behaviour (Cossalter, 2006; Sharp, Robin S. and Limebeer, 2001; Pacejka, 2012).

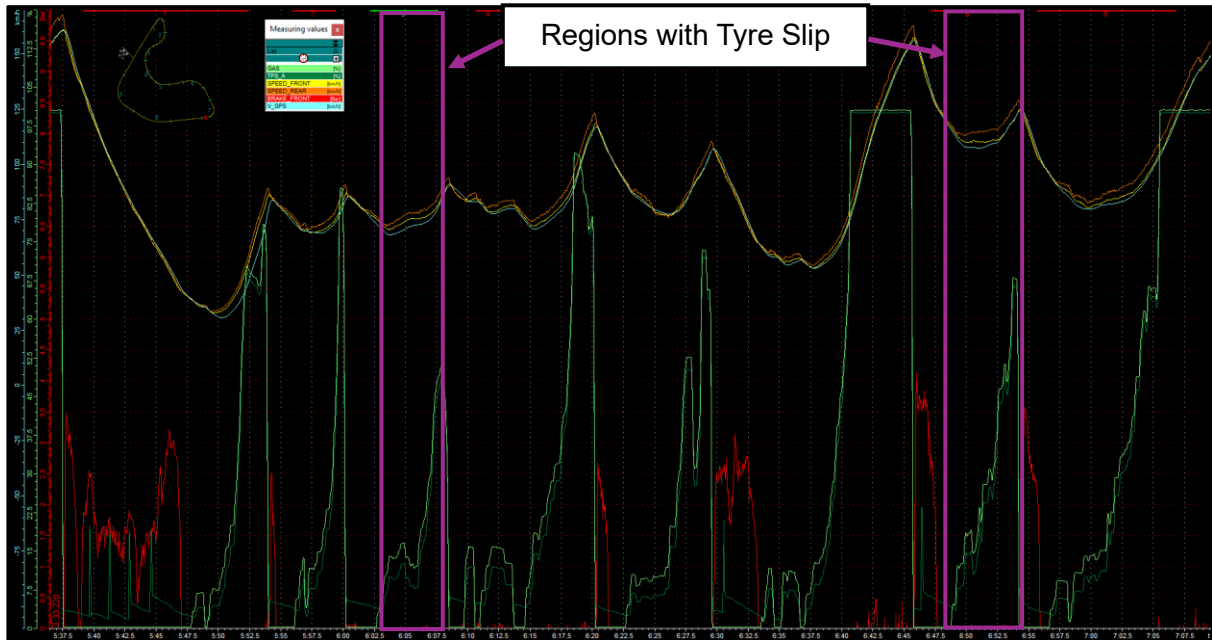


Figure 12: Graph of Brake Pressure, Throttle, and Speed of Fastest Lap Session 2 with Highlighted Rear Tyre Slip Regions

6.2.2 Throttle Position and Longitudinal Acceleration

In Figure 13 increases in throttle (green) produce corresponding rises in longitudinal acceleration (white). However, there is one instance where there was consistent throttle input with a sudden change in acceleration. This event occurred mid-corner at turn six.

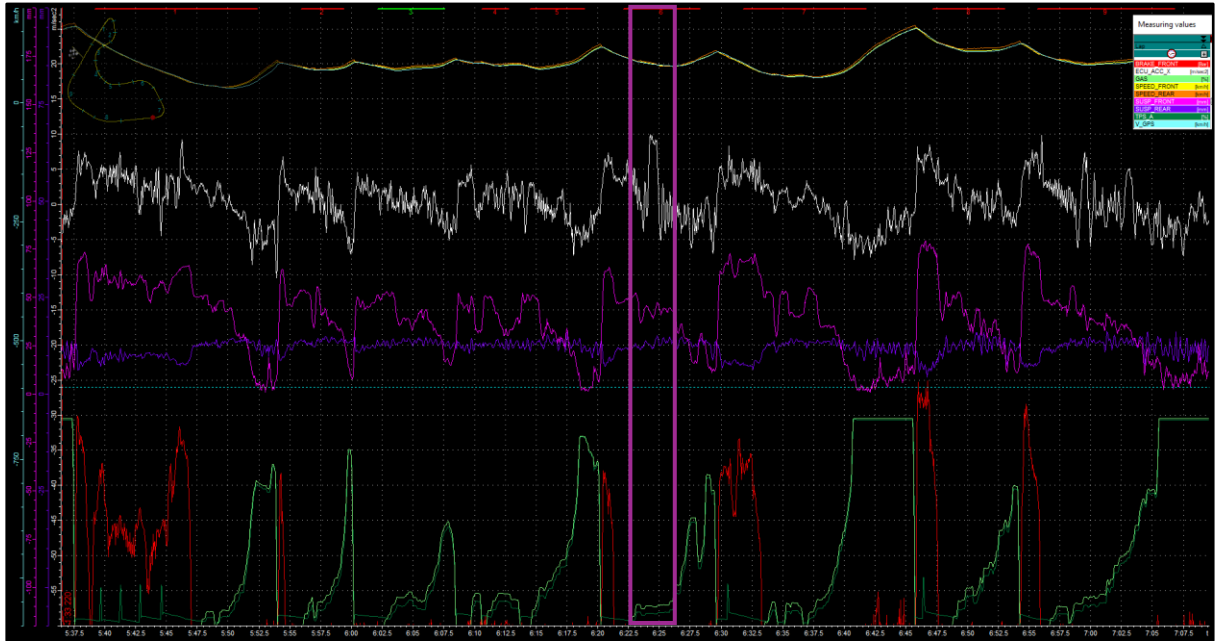


Figure 13: Graph of Brake Pressure, Suspension Travel, Acceleration in x Throttle, Front Brake and Speed of Fastest Lap Session 2 with Highlighted Event at Turn Six

6.2.3 Suspension Travel and Brake Pressure

Peaks in brake pressure (red) coincide with rapid increases in front suspension travel (pink), indicating load transfer to the front forks during braking. The front suspension travel trace shows progressive compression with some small oscillations after then initial peak. This suggests that the damping is effective on the forks. This is true for all the suspension trace shown, implying that the suspension had a predictable response.



Figure 14: Graph of Brake Pressure, Suspension Travel, Acceleration in x Throttle, Front Brake and Speed of Fastest Lap Session 2 with Example of Front Suspension Behaviour During Cornering Highlighted

6.2.4 Lean Angle and Rider Lean

The upper graph compares roll rate (GYRO) from the motorcycle (red) and rider suit (blue), while the lower plot shows lean angle from the bike logger. Strong correlation between both roll signals however the rider trace shows higher amplitude and variation. This suggested that upper-body movements and corrective inputs were undertaken. At corner entry and exit the roll rate peaks aligned with the fast changes in lean angle. Reduced oscillations at higher speeds section of the track a line with the increase in dynamic stability from gyroscopic forces (Zhu, Murakami and Nishimura, 2012).

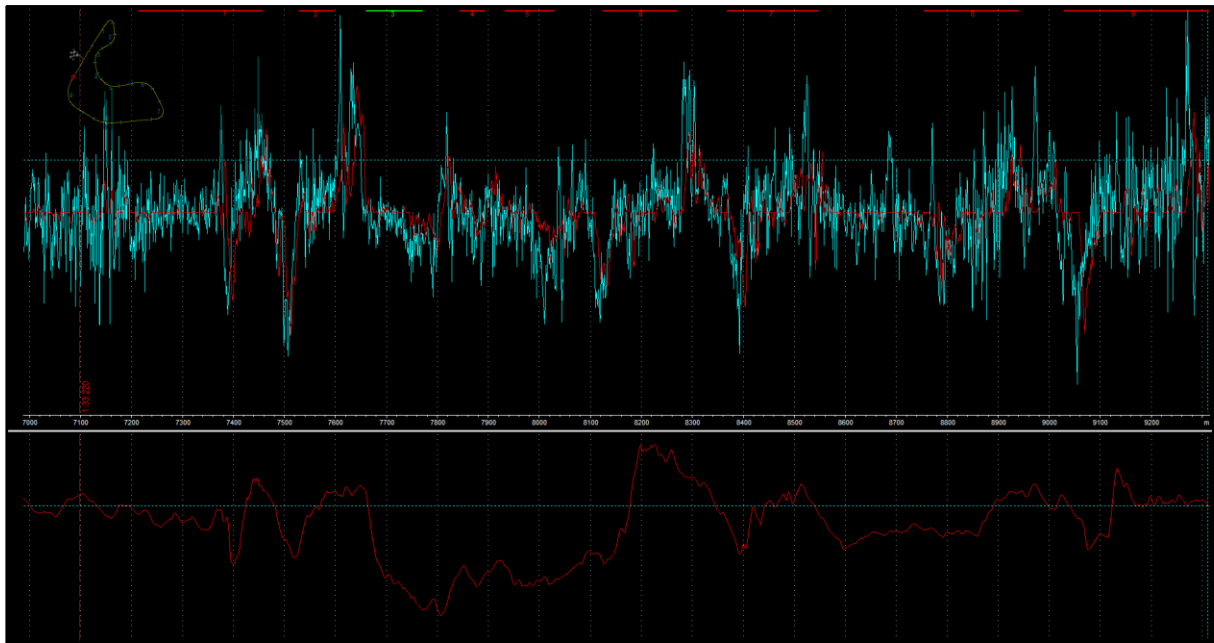


Figure 15: Upper Graph- Bike and suit Gyro about the x-axis of Fastest Lap Session 2 Lower Graph-Bike Lean Angle from the Bike Logger

6.2.5 Strain Gauge Data

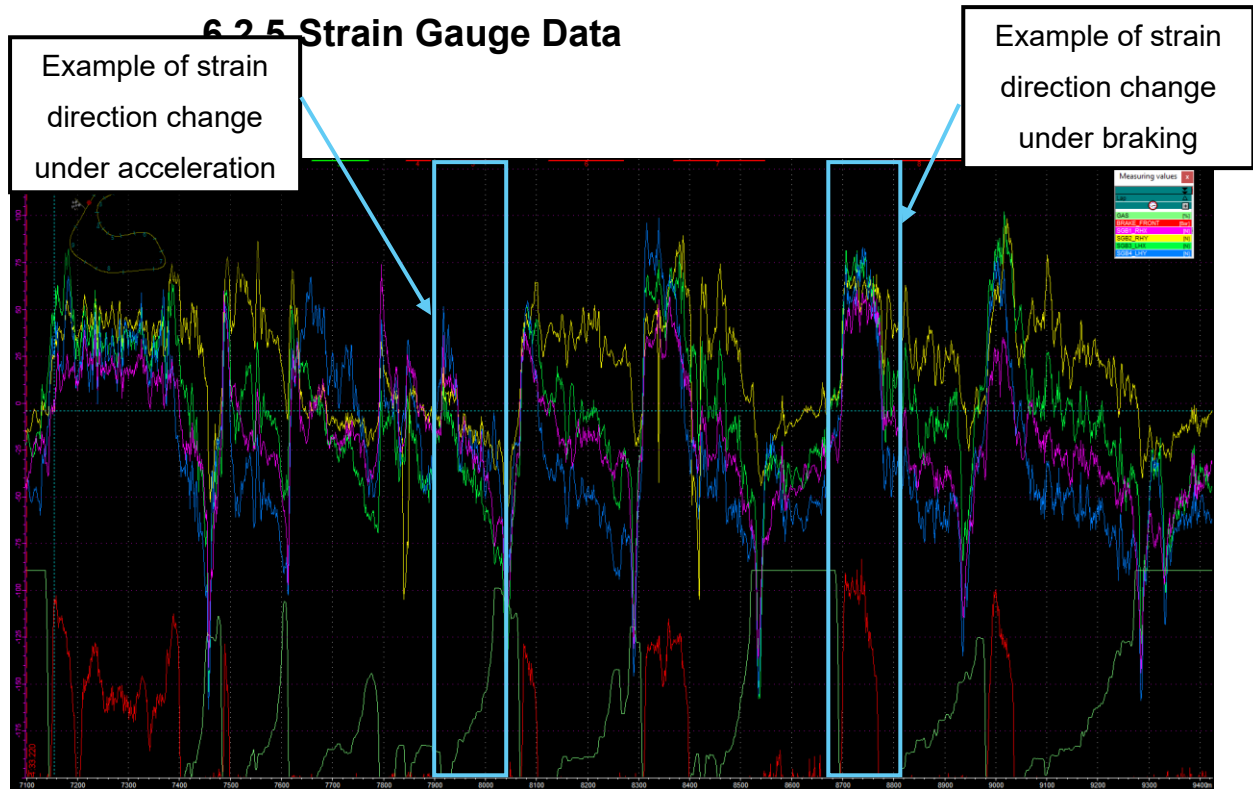


Figure 16: Graph of Handlebar Strain, Throttle and Front Brake for Fastest Lap Session 2

Strain in the handlebars was measured on the left and right in the x and y directions. On average, strain in the right handlebar (yellow) in the y direction was the greatest, this is likely due to the throttle and front brake being placed on this handlebar. During use of the front brake strain dramatically increases. This was expected and had multiple rational for this behaviour. Firstly, under braking the riders applies a force to the front brake lever; the deceleration causes weight transfer to the front of the bike therefore strain on the handlebars will increase as the rider resist this movement. Furthermore, if the rider implements the technique of counter-steer then strain will increase during cornering as they apply a force to the handlebar. Due to rearward weight transfer during acceleration strain on the handlebar changes direction as the rider increases the throttle percentage (green on the lower graph).

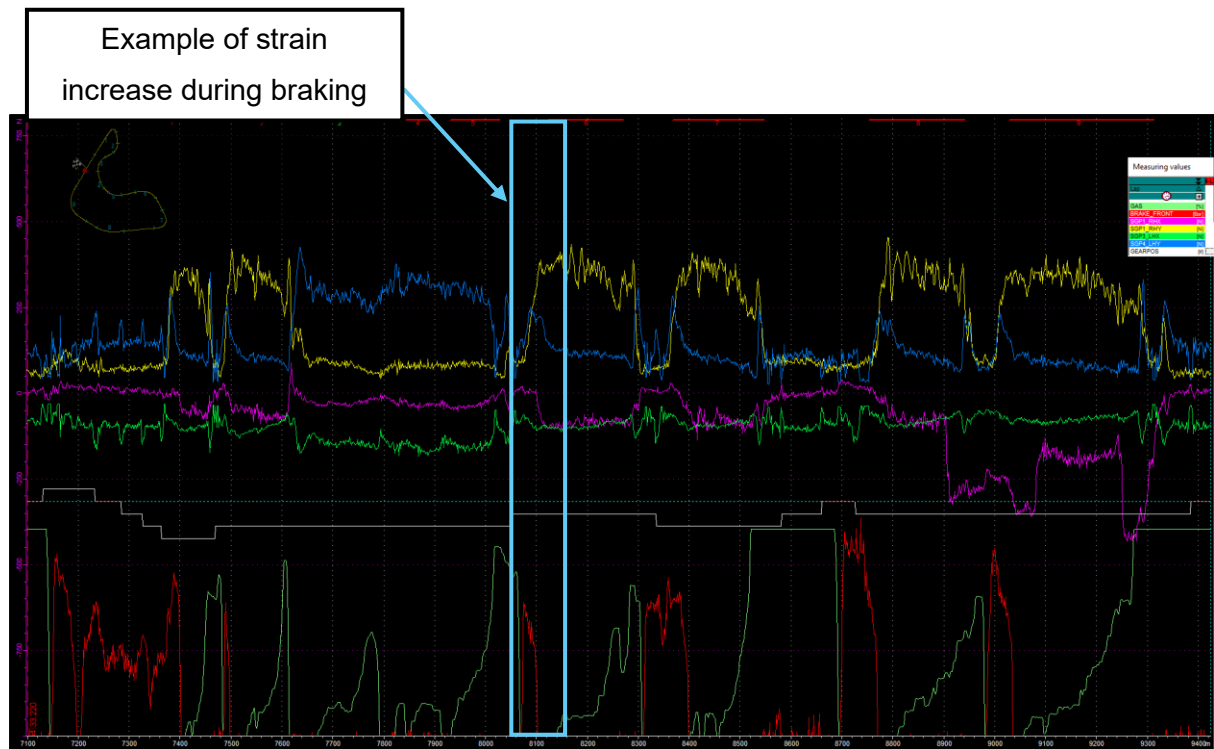


Figure 17: Graph of Footpeg Strain, Throttle, Front Brake and Gear Position for Fastest Lap Session 2

Strain in the footpegs was measured on the left and right in the x and y directions. On average, strain in the right footpeg (yellow) in the y direction was the greatest, this is likely due to the track containing mostly right-hand corners. Strain in the y direction increased during or shortly after braking. This was due to the rider initiating the lean into the corner. When turning right the strain in the right foot peg increased (yellow) and when turning left the strain in the left foot peg increased (blue). The magnitude of the y direction strain peaks were lesser during left corners compared with right turns. This implies that more weight transfer occurred during right turns. Greater, weight transfer can lend itself to more lean angle and therefore greater cornering speed.

7.0 Discussion & Conclusions

Overall, the Aprilia RS660 is a well-balanced motorbike with favourably handling characteristics and stability.

7.1 Future improvements

If these studies were to be repeated there are some improvements that could be made to support the results accuracy. An example of this would be to add more sensors to the bikes. The more data streams available to a data engineer the more accurately they can make statements about the behaviour of the bike. A useful addition to the bikes would be pressure matrix pads placed in the seat and on the side of the tank. These would give more insight into the rider's inputs as the weight distribution of the rider could be more accurately measured. This would improve the understanding of cornering behaviour as the riders lean into the corner greatly effects the dynamics.

8.0 Professional Development

The author has greatly developed their understanding of motorcycle characteristics. Prior to the project the author did not have any practical experience in the analysis of motorcycle specific data. Furthermore, their understanding of the 2D software has improved as MoTeC was used solely in the past.

9.0 References

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10.0 Appendices

Setup changes	Definition	Effects on Behaviour
Suspension Springs	Mechanical system that absorbs irregularities in the road can be monoshock or dualshock	Increasing the spring stiffness, improves stability but decreasing compliance over bumps which can reduce mechanical grip. Reduced stiffness improves compliance and grip over uneven surfaces and an increase dive and squat. Furthermore, the suspension can bottom out. (Cossalter, 2006) (Sharp, Robin, 2010)
Damping	Hydraulic resistance mechanism that is part of the suspension assembly. It limits the speed of compression and rebound	Increased damping slows compression which can improve stability and reduce settling time but can reduce bump absorption and grip. Reducing damping causes the suspension to respond more quickly to surface irregularities, improving compliance but potentially causing instability and uncontrolled oscillations. (Sharp, Robin S. and Limebeer, 2001) (Foale, 2002)
Rake	The angle between the steering axis and the ground	The greater the rake the greater the straight-line stability while steering response decreases. The opposite is true for lesser rake angles (Cossalter, 2006) (Kooijman and Schwab, 2013)
Preload	The initial compression applied to the suspension before external loads are applied e.g vehicle weight	Increasing preload decreases suspension sag and has the potential to improve responsiveness. When preload is reduced sag increases and reduced suspension travel (Foale, 2002) (Cossalter, 2006)
Tyre Pressures	Internal gas pressure within the tyres	Greater tyre pressure stiffens the tyre and reduces the contact patch this reduces grip and feedback to the rider. Reduced pressures increase the contact patch which can improve grip and

		compliance but can cause instability in the tyre (Pacejka, 2012)
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